Surfaces that Shed Dust:

Development, Performance and Characterization

G. Devaud, A. Lawitzke, M. Crowder, R. Stover
(BATC)
X. Wang, A. Dove, S. Robertson, M. Horanyi
(CCLDAS)

Who we are: Ball Aerospace and Technologies

HUBBLE space telescope

all the science instruments on board Hubble will be Ball Aerospace-built.

LATEST NEWS: Ball/Boeing Team Completes Segment Testing of Space Surveillance Satellite System

Ball Aerospace sponsors PBS documentary, "400 Years of the Telescope." Read more...

CAPABILITIES

Space-based Instruments and Sensors

Learn more about space-based instruments and sensors capabilities in these exciting programs: James Webb Space Telescope, HiRISE, Deep Impact and CALIPSO.

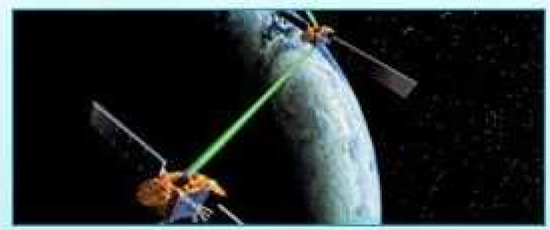
PROGRAMS

Program Profile: Hubble Space Telescope

The historic mission to service NASA's Hubble Space Telescope included the installation of two instruments built by Ball Aerospace.

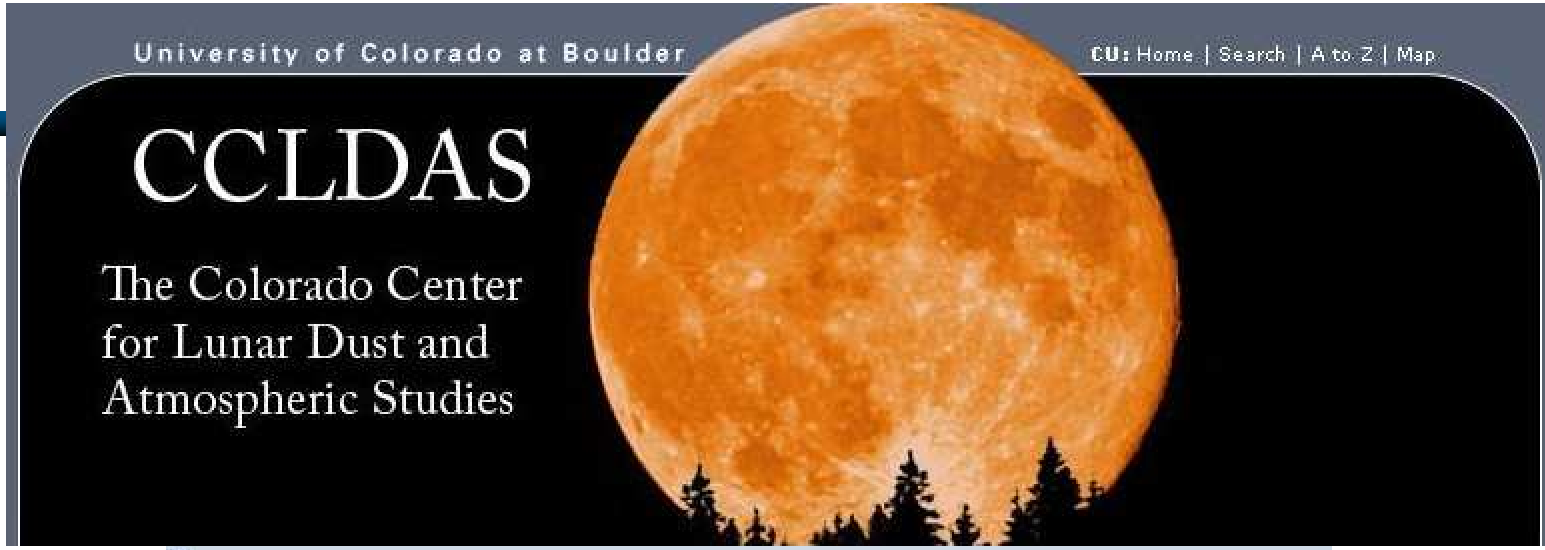
PRODUCTS

Aerospace Technology & Components



Ball Aerospace has 30 years of experience in Earth- and space-based laser communications that support military, scientific and commercial markets. Learn more about our products and markets.

Who We Are: CCLDS



About CCLDAS

We study the lunar dust/plasma environment through a combination of modeling, theoretical work and laboratory experiments.

We develop new experimental processes to determine:

- The effects that a charged surface mobilizing dusty particles affects the lunar atmosphere
- How solar radiation is responsible for the lunar dusty atmosphere
- How dust can be mitigated on lunar missions

D.R. Scott (Apollo 15). The apparent "haze" above the hills is caused by dust on the camera lens. (Courtesy of NASA)

We provide experimental facilities to scientists and institutions around the world with the following capabilities:

- *Dust accelerators:* 3 MeV and 'mini' 20 kV
- *Large and small test chambers:* includes lunar environment simulators
- *Main Lab:* ~5000 ft^2
- *Office/Conference Space:* ~5000 ft^2
- *Lab founded:* 2009

Motivation: Limiting terrestrial particulate contamination

Engineers at Ball Aerospace examining Be mirror for the James Webb Space Telescope for particulate (dust, lint) and molecular contamination.

Motivation: Limiting moon dust contamination

Apollo 17 commander Eugene Cernan after a day of moonwalking.

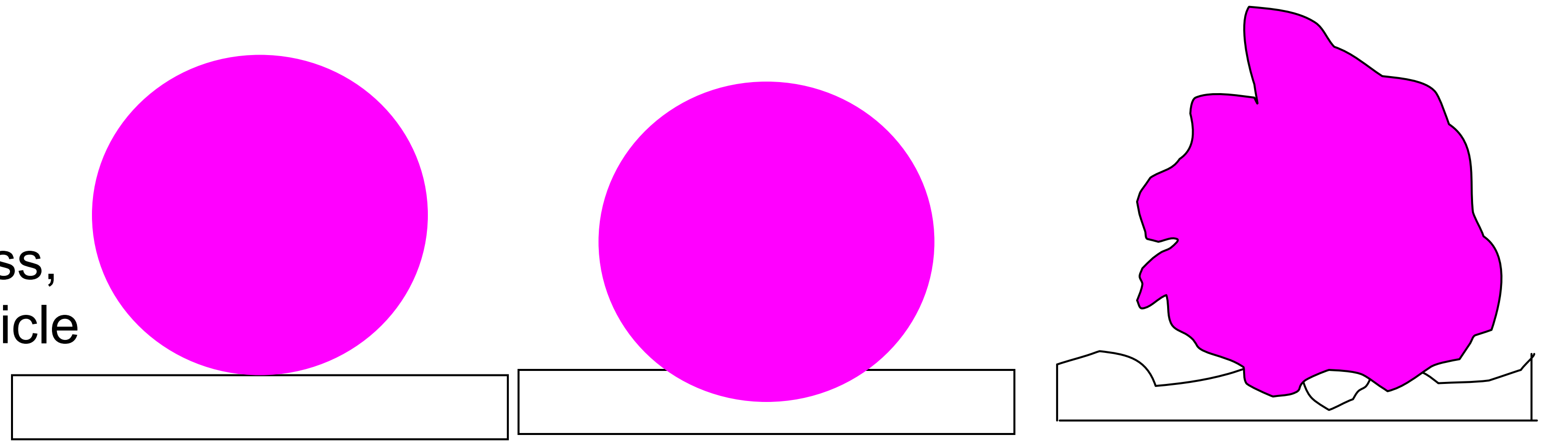
The Goal

- **THE BIG GOAL: ENGINEER SURFACES SUCH THAT DUST IS NOT ATTRACTED TO THE TARGET SURFACE AND IF IT ENDS UP THERE, CAN EASILY BE REMOVED.**

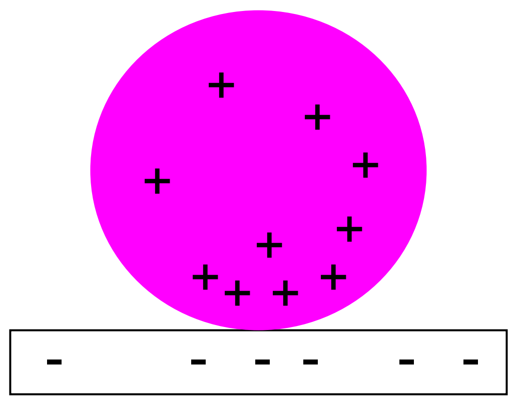
- **THE SUB-GOAL: TO EXPLORE AND UNDERSTAND UNDERLYING MECHANISMS AS A PATHWAY TO THE BIG GOAL.**
  - EMPIRICAL WORK
  - CHARACTERIZATION

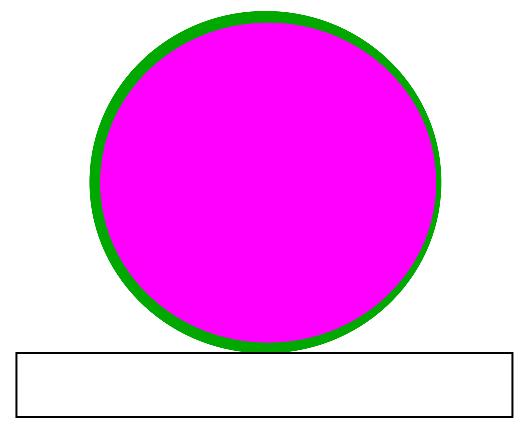
Adhesion: An extremely complex phenomenon

Contact area:
Effect of hardness,
surface and particle
morphology



Coulomb force,
charge transfer,
Van der Waals
(induced dipole
Interaction)

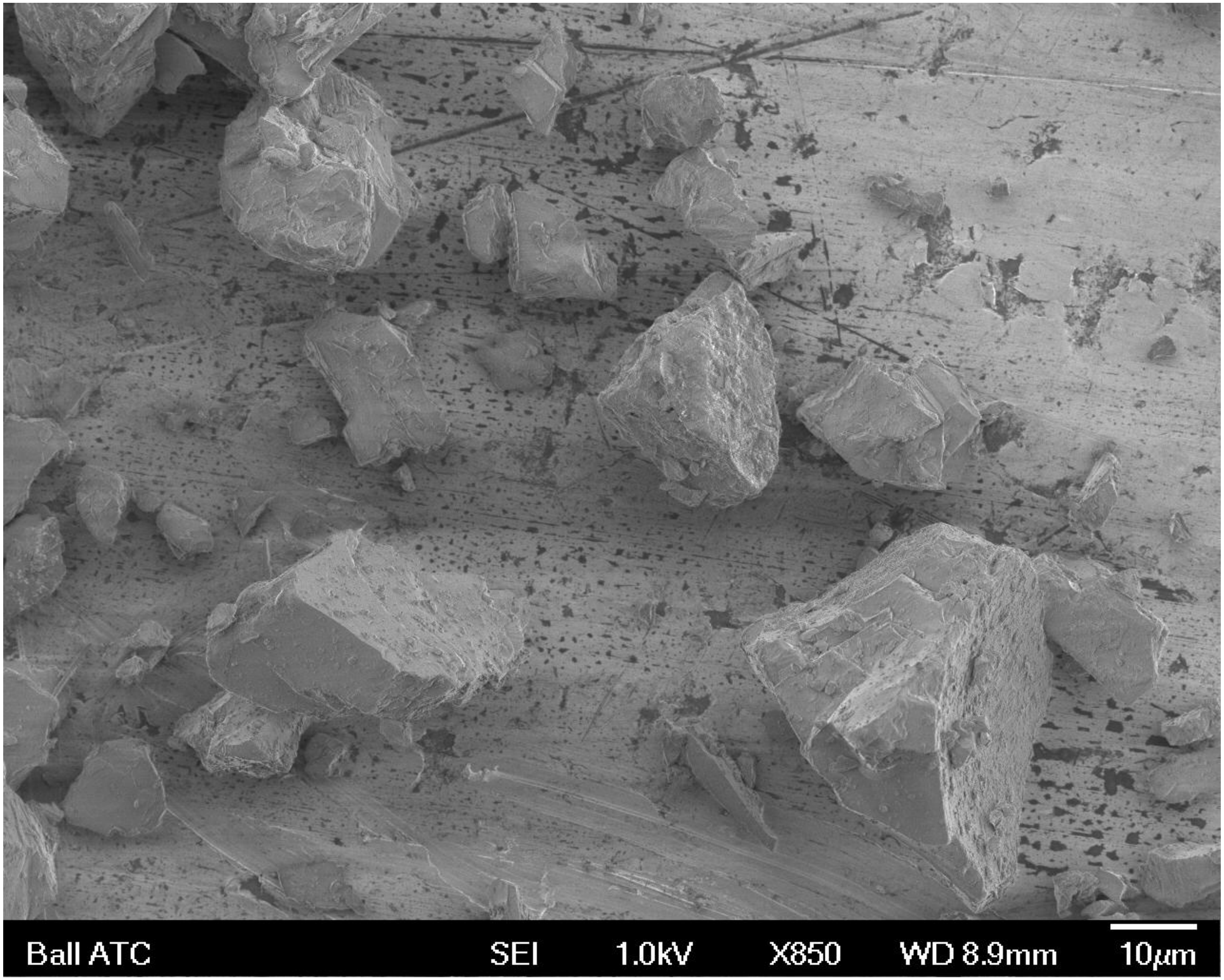




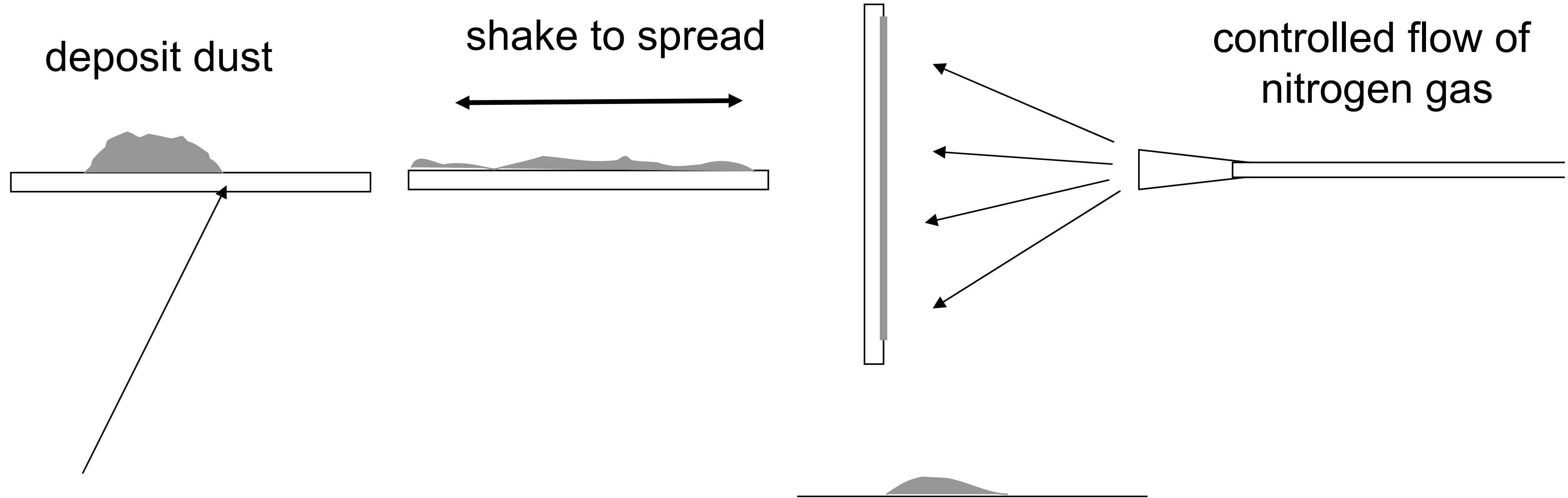
Surface films: oxidation,
humidity, chemical reactions

Others: magnetic effects, sintering, interfacial mixing, alloying, etc….

Our Dust: JSC-1AF Simulant



Deposition and Removal of Dust

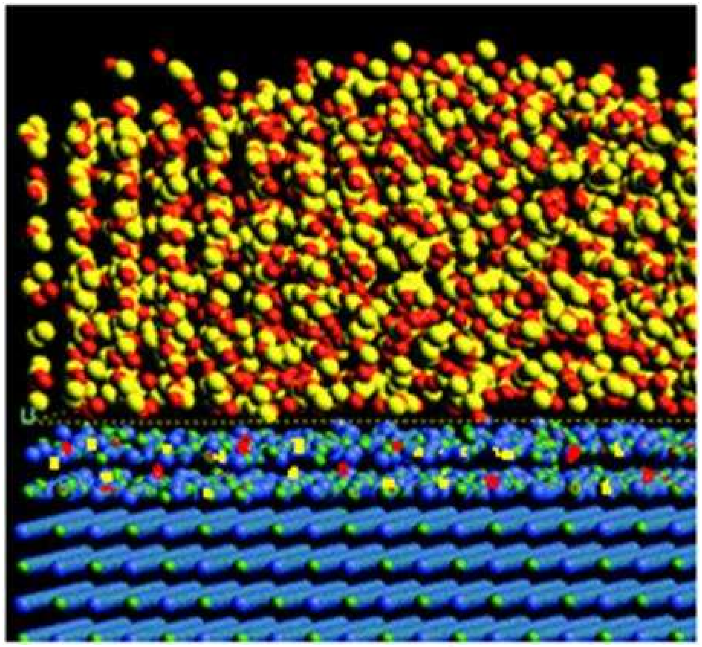


Substrates: black Kapton, silicon, polycarbonate, quartz (~1 sq. in)

with various

Surface Types: Virgin, Teflon-like coating, BATC proprietary treatment

Film Growth & Surface Modification

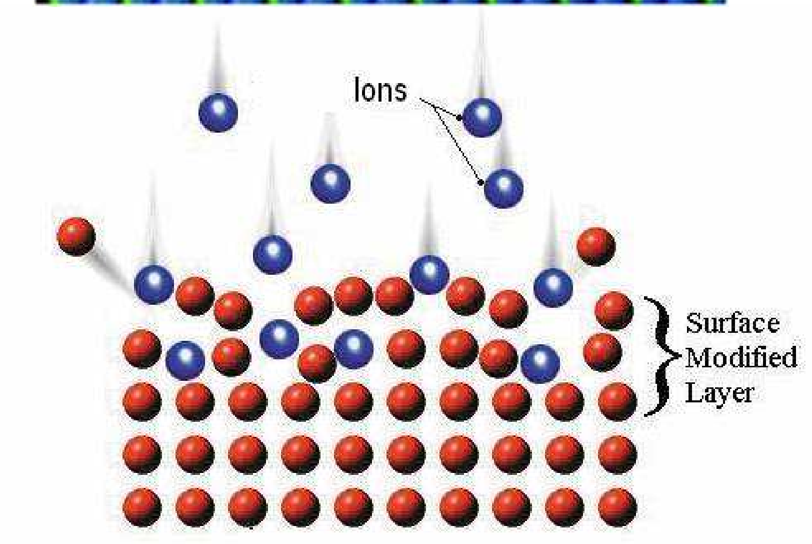


Film Deposition:

Material added to a substrate.

Thicknesses vary from monolayer coverage to relatively thick films.

Interfacial layer depends upon the conditions of the deposition and type of substrate.



Surface Modification:

No net increase in thickness.

Surface composition modified. Balance between surface etching and deposition.

Black Kapton partially coated with C:F film

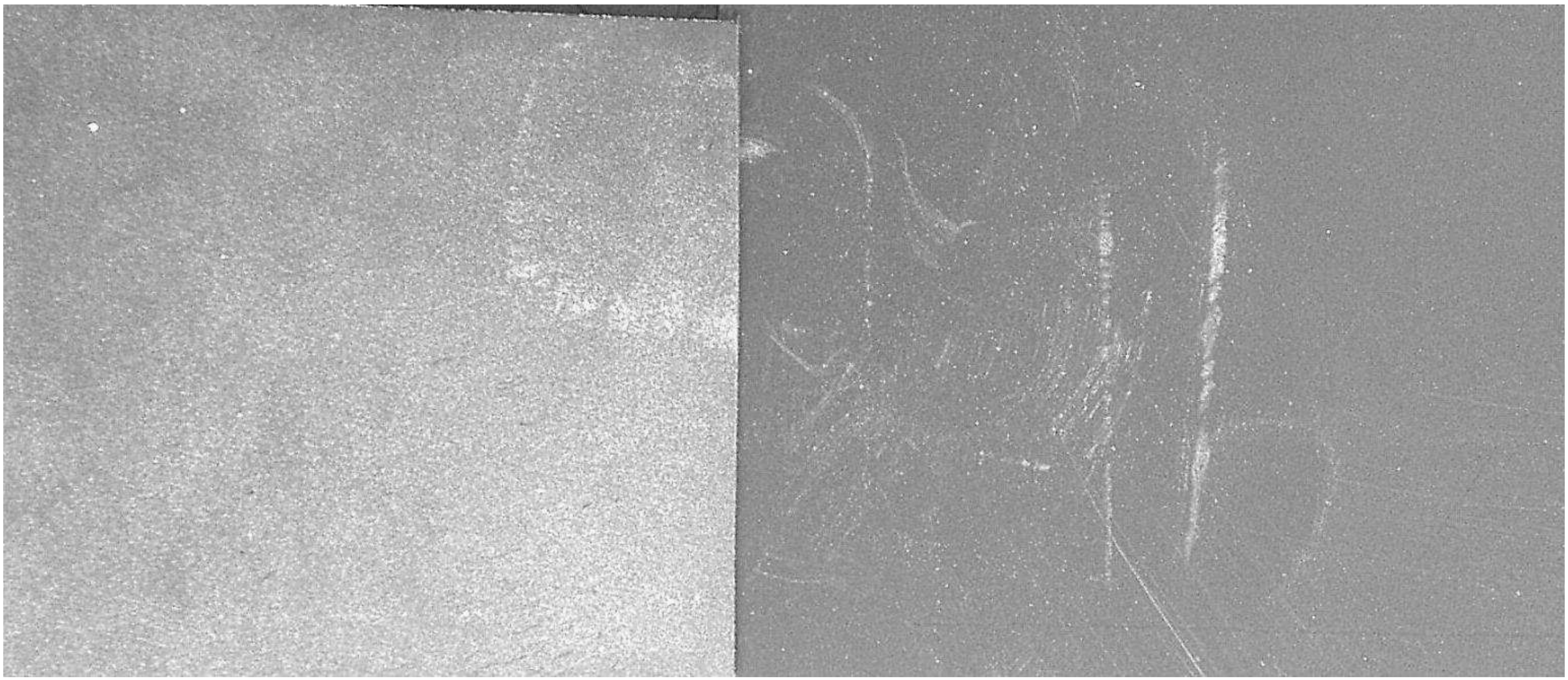
Black Kapton w/o Coating

Protective Coating

JSC-1AF (5 -45um) Lunar Simulant applied to full Kapton Sample

When tapped, the Lunar simulant readily falls from the Coated side of the Sample, while adhered to the uncoated side of the Kapton sample.

Black Kapton: Virgin and Treated

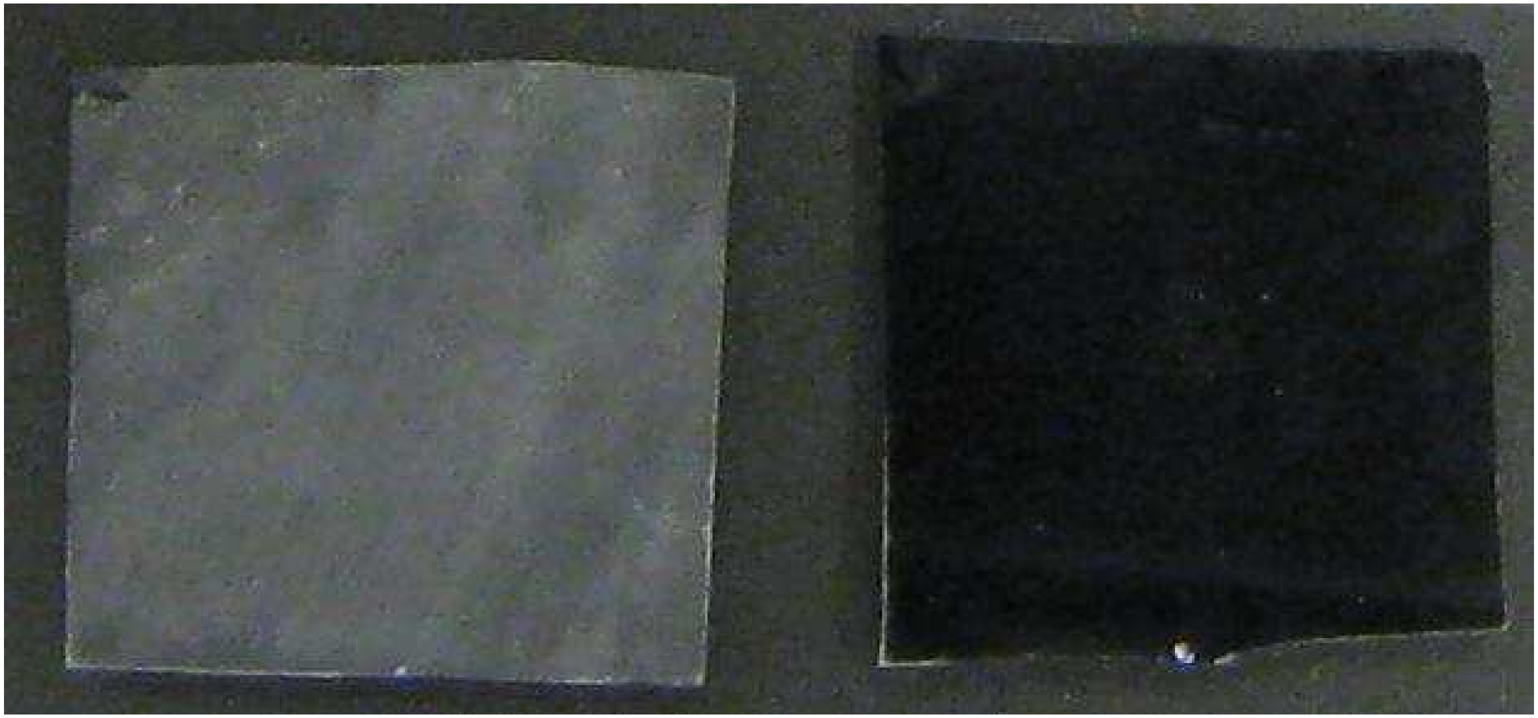


Virgin/dusted

Treated/dusted

BATC proprietary surface treatment

Silicon wafer: Virgin/dusted and treated/dusted

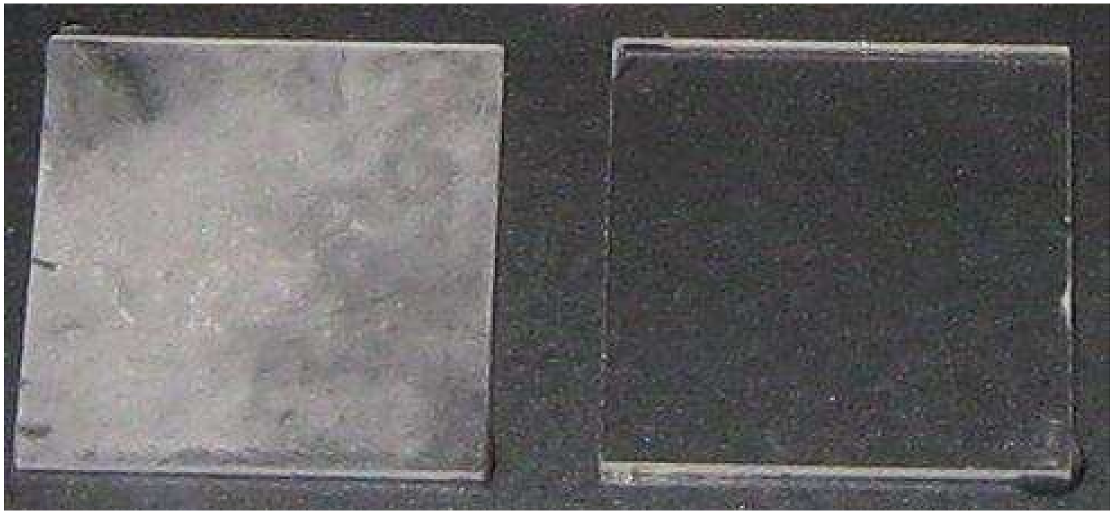


Virgin Si after dusting

Treated Si after dusting

BATC proprietary surface treatment

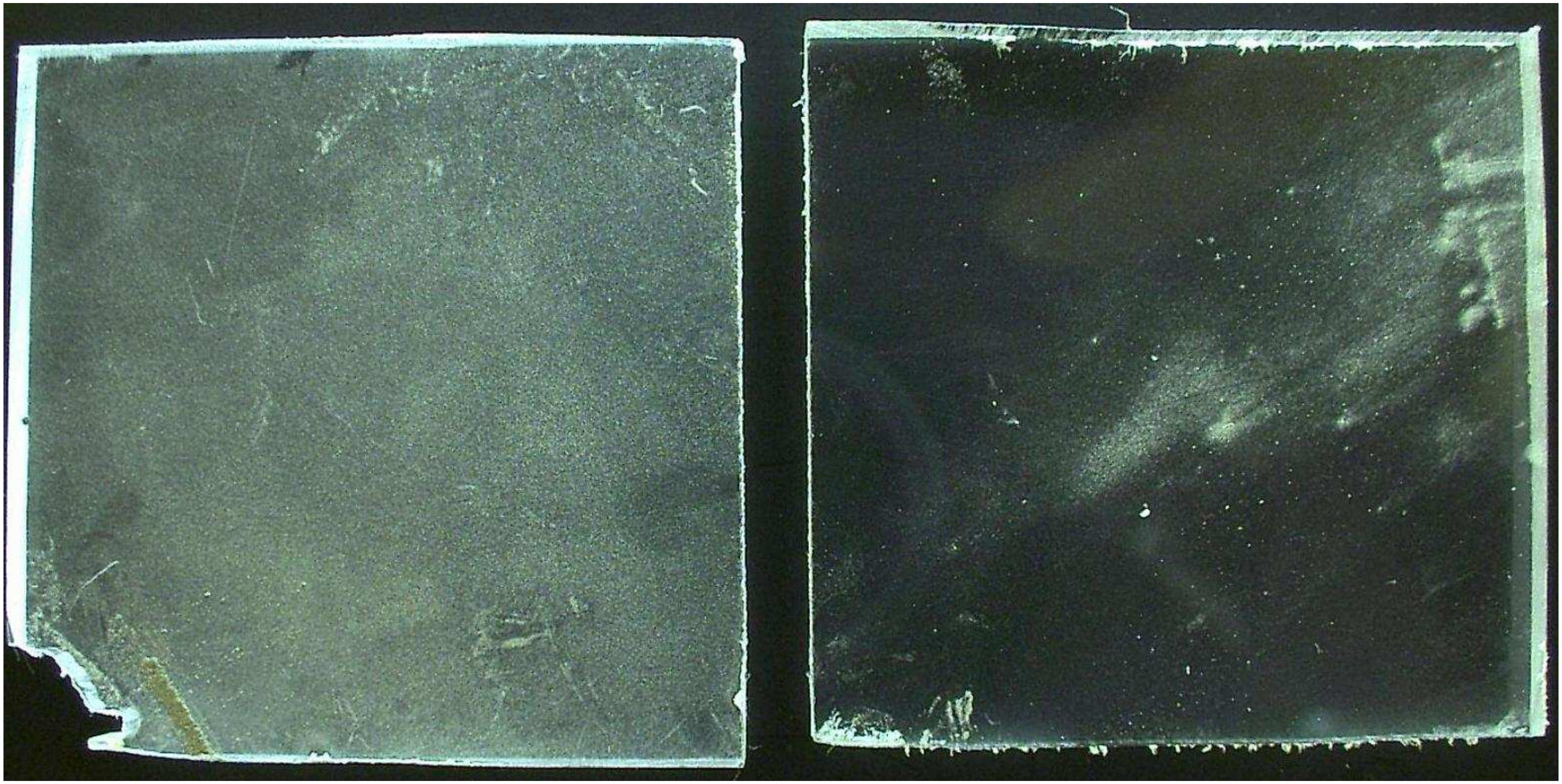
Quartz: Virgin/dusted and treated/dusted



Virgin quartz after dusting   Treated quartz after dusting

BATC proprietary surface treatment

Results: Polycarbonate



Virgin polycarbonate after dusting

Treated polycarbonate after dusting

BATC proprietary surface treatment

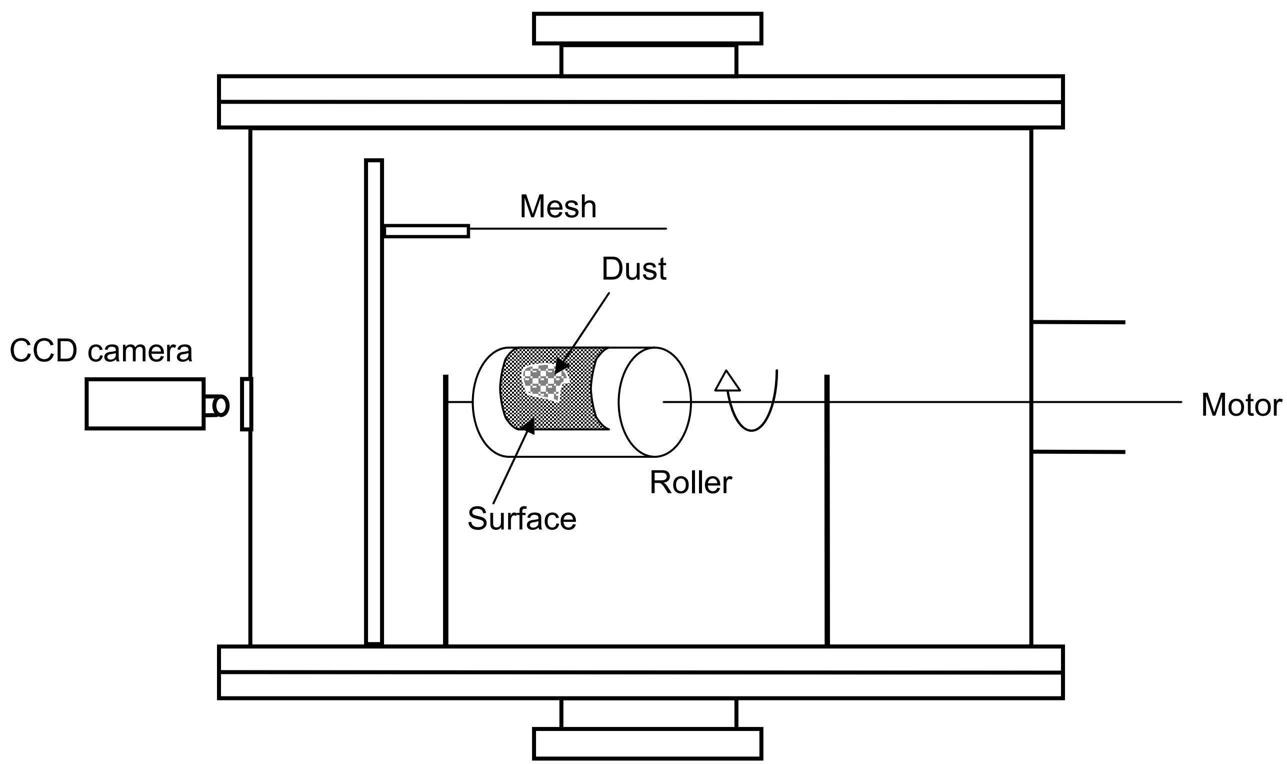
Summary of adhesion results:

In air:

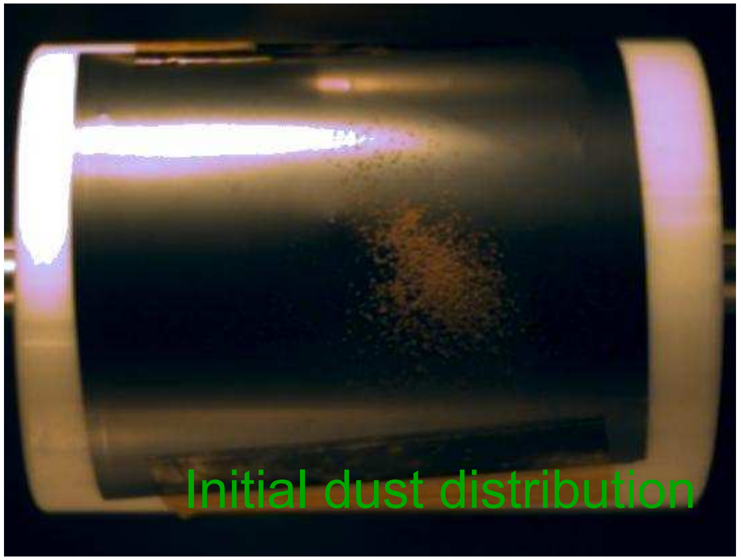
- Dust adheres well to virgin substrates (black Kapton, silicon, polycarbonate, quartz) and coated (a:C:F) silicon, polycarbonate, quartz.
- Dust does NOT adhere to coated black Kapton.
- Dust does NOT adhere to BATC proprietary treated black Kapton, silicon, polycarbonate or quartz.
- Consistent results have been observed numerous times.

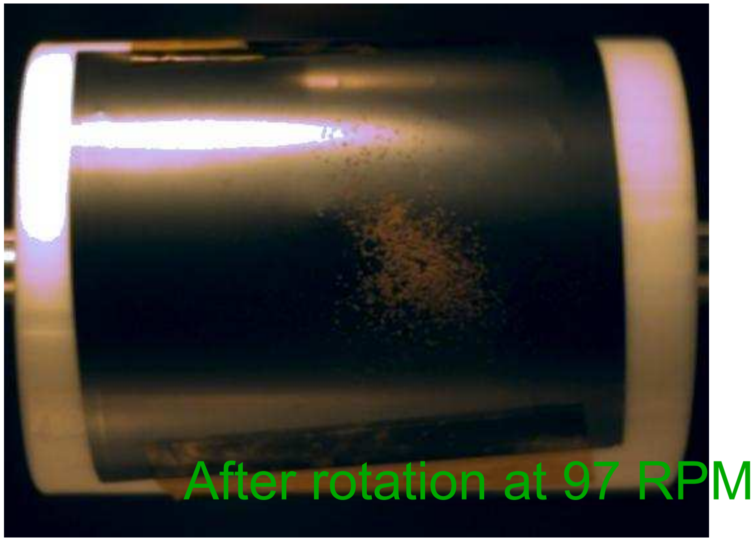
Measuring Adhesion Force

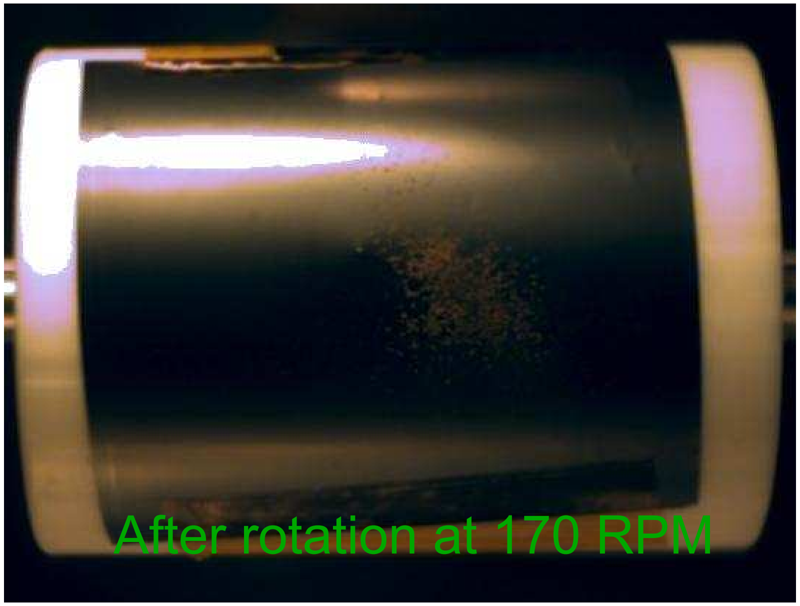
- **Centrifugal force detachment: Measures total adhesion**
- Atomic Force Microscopy
- Electric field detachment

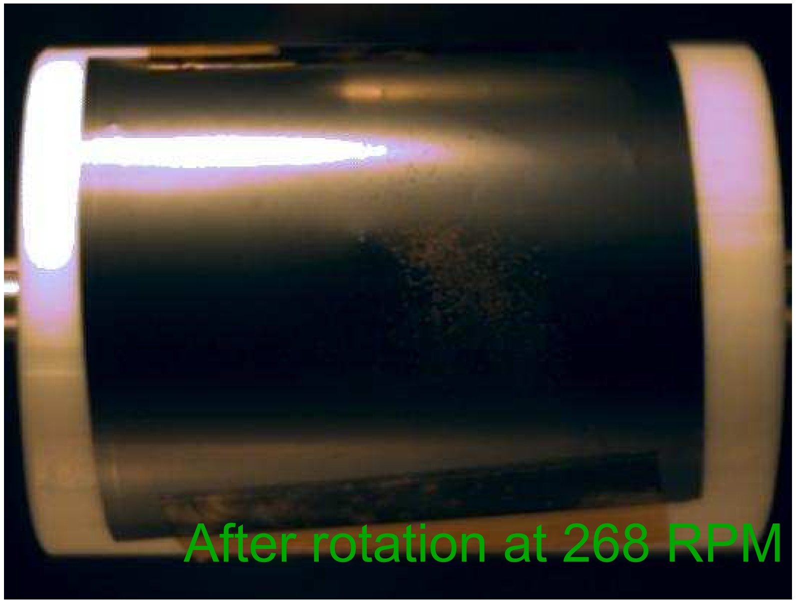


Coated Black Kapton (multiply by 3 for speeds) < 25 micron particles JSC-1









First results for black Kapton

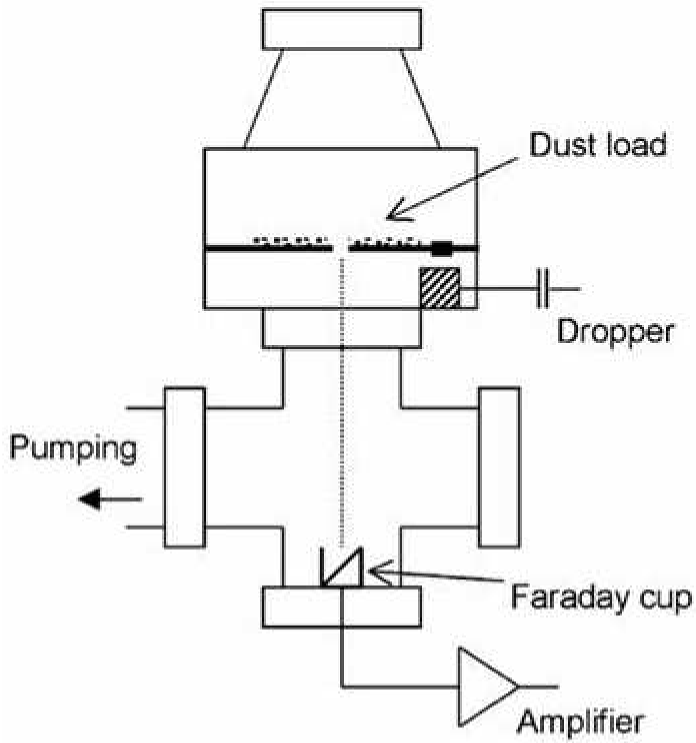
From the roller/centrifugal force experiments:

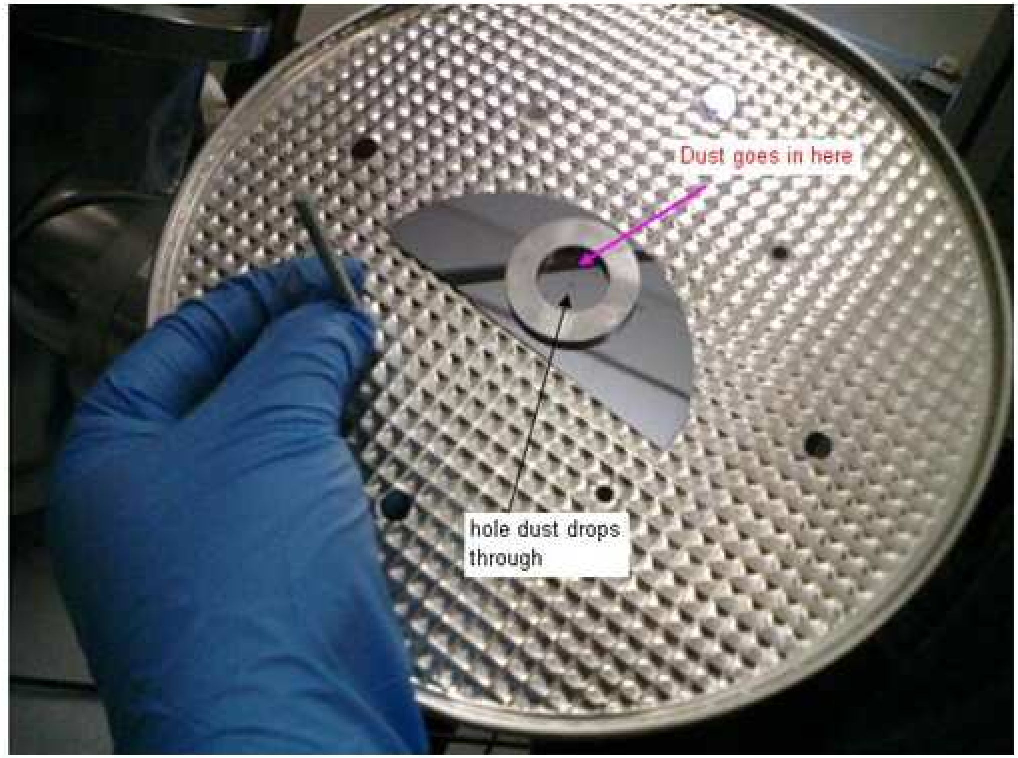
All done under vacuum, on the order of 1-3x10^-6 torr

First "major" removal of dust:

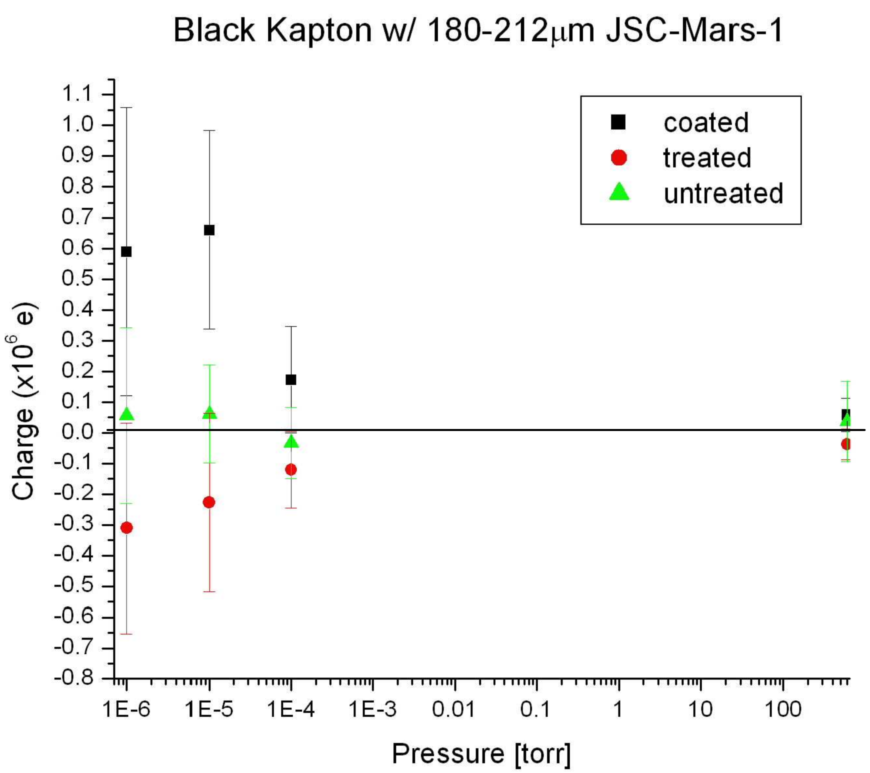
--> Coated has lower adhesion than untreated
--> Treated has lower adhesion than untreated (perhaps even lower than coated)

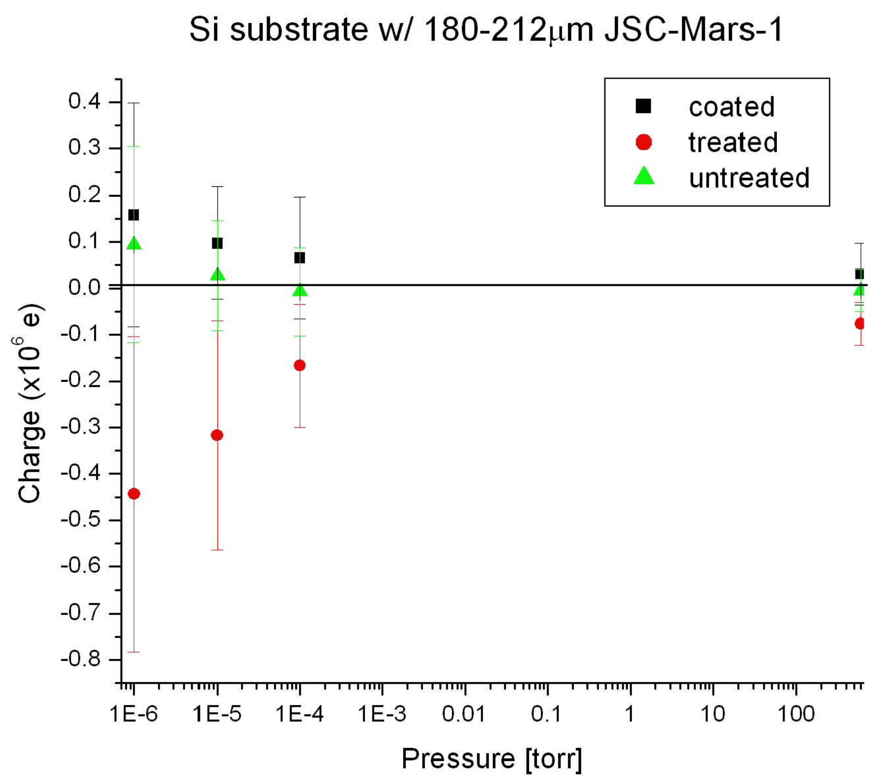
Measurement of Contact Charging:





Contact Charging Data

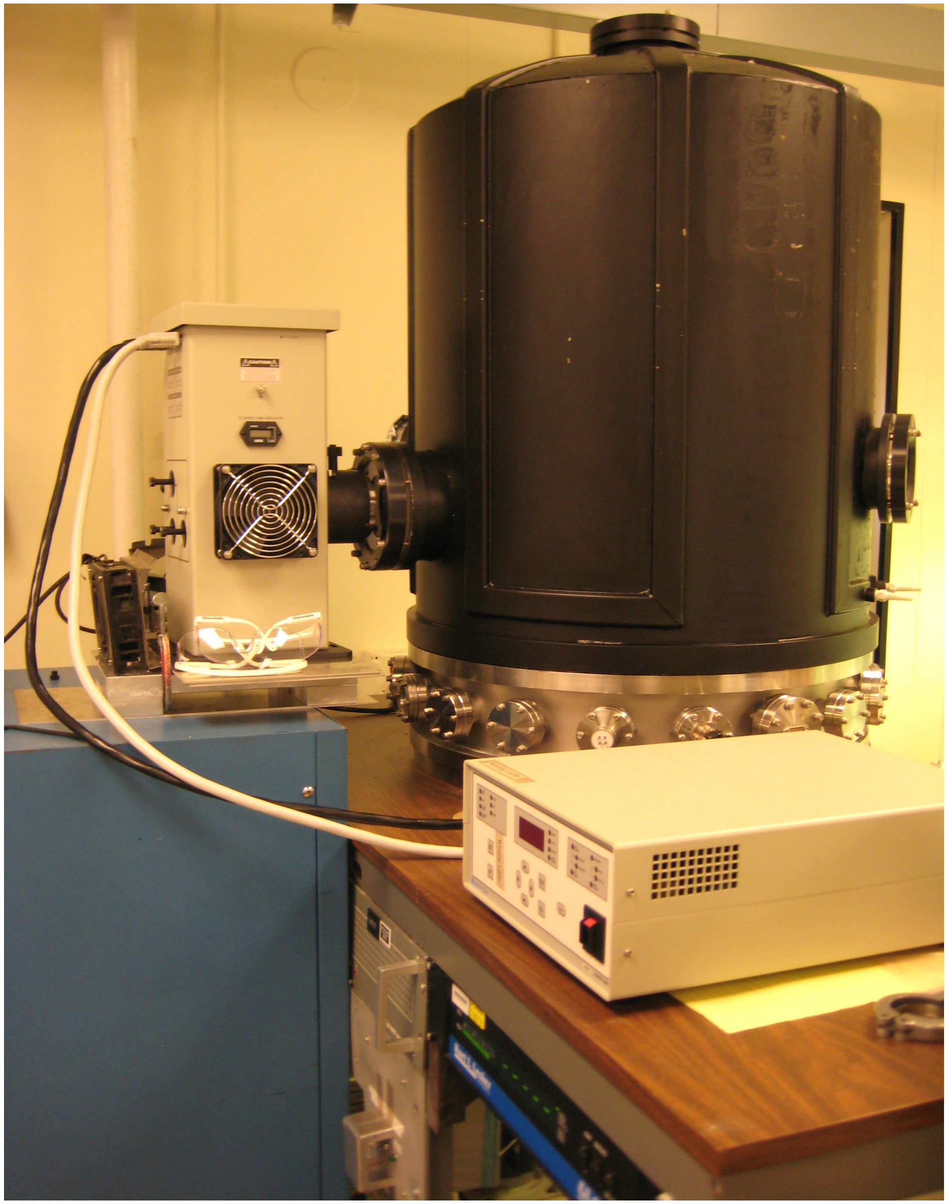




- **The magnitude of the charge transfer is substantially greater with increased vacuum, as compared with air.**
- **Particles which move across the coated film (amorphous C:F) donate electrons.**
- **Particles which move across virgin surfaces pick up very little charge; the charge transfer is the lowest of all types of surfaces.**
- **Particles which move across treated surfaces pick up small negative electric charge.**

Future Work: Effect of UV irradiation on treated surfaces

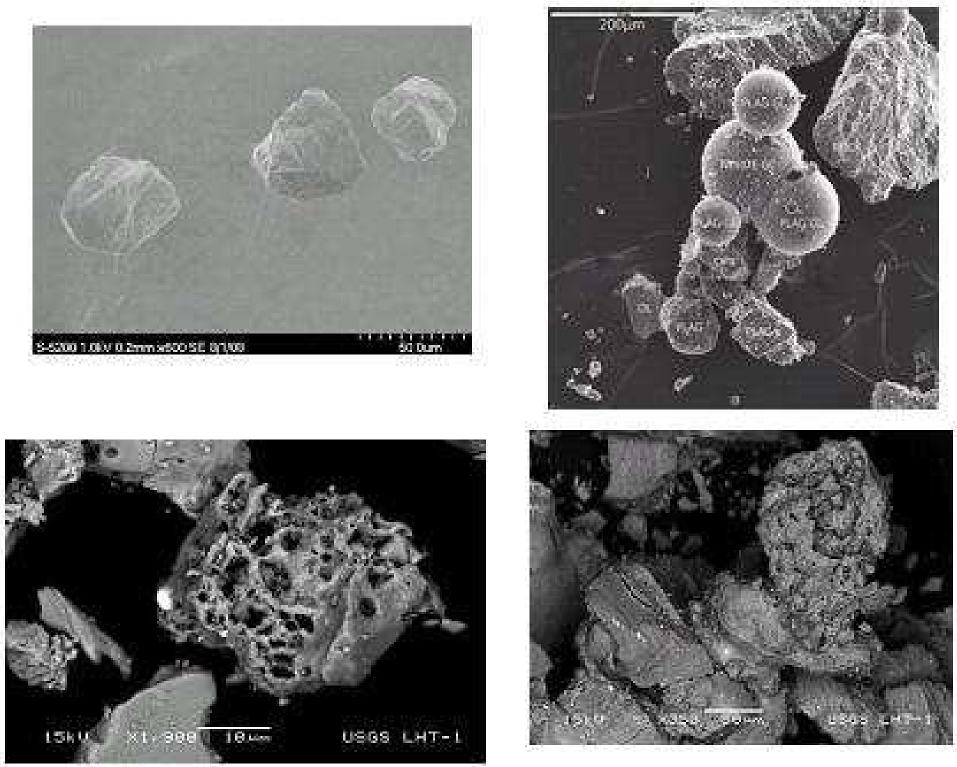
- Simulate extraterrestrial UV environment
- UV Sources:
  - Hg(Ar)
  - Xenon
- Irradiance - function of:
  - Distance from source
  - Exposure Time
- Study:
  - How UV exposure impacts particle adhesion



Xenon lamp into chamber window

Future Work:

Refinement of process parameters for producing surfaces which shed dust, including other types of materials: metals, space suit material, etc.



Effect of size,

type,

morphology,

plasma, UV,

environment….

Lunar Simulants: Top left is JSC-1AF, the other images are those of various ZAP lunar simulants.